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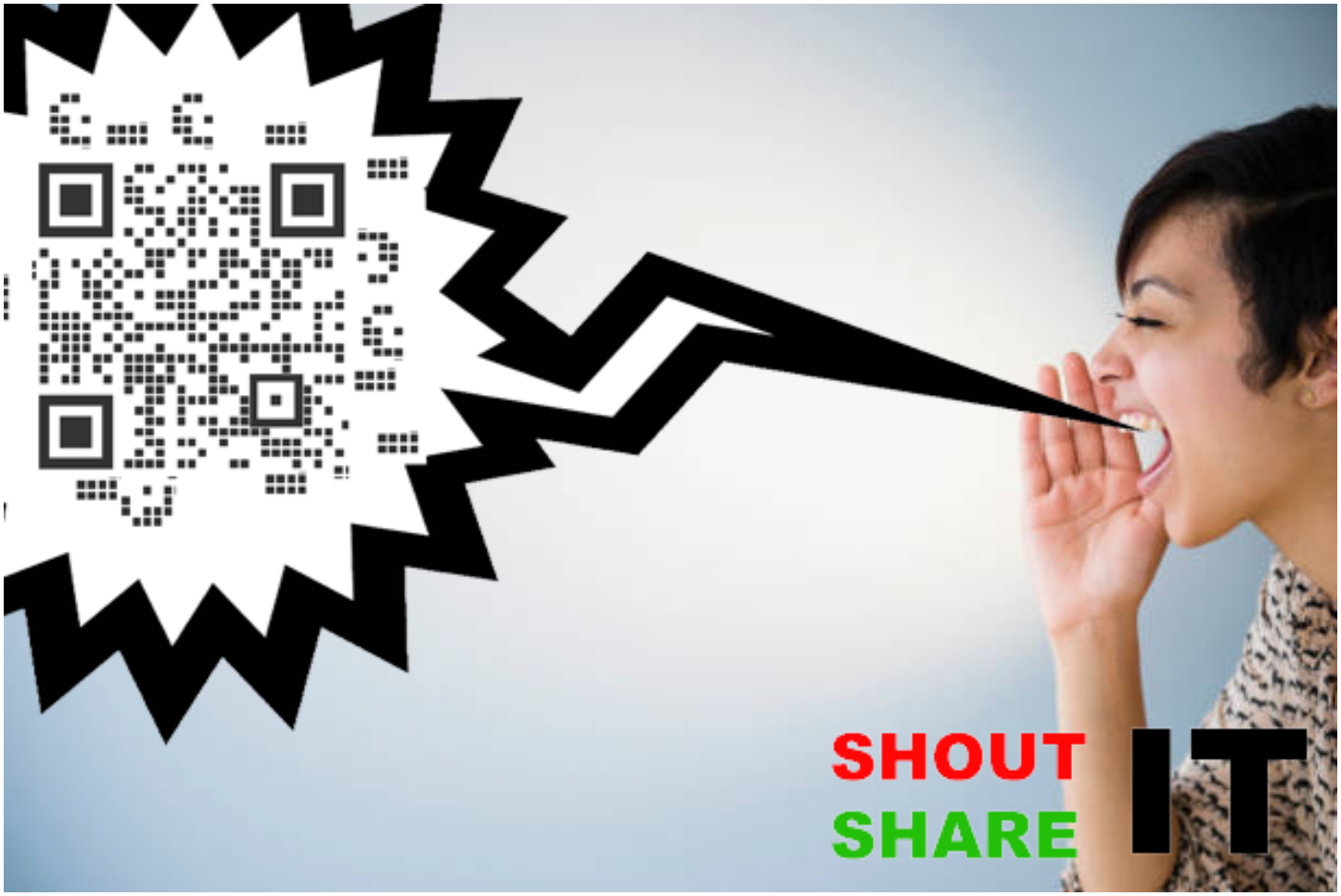
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A PHYSICAL AND CHEMICAL STUDY OF MILO AND FETERITA KERNELS.

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PURPOSE OF INVESTIGATION.

The grain sorghums are a comparatively new crop in the United States, where they have been grown for only 25 or 30 years (2).[1] At first their use was largely restricted to the feeding of farm animals. These grains, however, are now being used in increasing quantities for human food and various industrial purposes, and are receiving attention from manufacturers of alcohol and starch. Feterita and milo, which contain on an average 65 per cent of starch, seem to be especially suitable as raw material for the manufacture of high-grade starch by commercial processes.

As a basis for a process utilizing nonsaccharine sorghums in the manufacture of starch and feeding stuffs, and to provide data for engineers who may be called upon to design machinery for their treatment, the Bureau of Chemistry has conducted a study on the physical characteristics and the chemical composition of milo and feterita kernels and the various parts into which they might be separated by milling. This study is a continuation of similar work done on the kafir kernel, the results of which are published in United States Department of Agriculture Bulletin 634. Milo and feterita have the same botanical characteristics and the kernels very much the same structure as the kafir kernel (Fig. 1). The data on corn and kafir herein reported are taken from Bulletin 634.

[1] The numbers in parentheses throughout this bulletin refer to the bibliography on page 8.

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PHYSICAL PROPERTIES OF KERNELS.

Fifty kernels of milo and 50 kernels of feterita were measured with a micrometer in three directions.[2] As the kernels lay on a flat surface, the vertical diameter was called the thickness, the distance from the hilum to the opposite end the length, and the dimension at right angles to these the width. The maximum, minimum, and average dimensions are given in Tables 1 and 2.

TABLE 1.—*Measurements of 50 kernels of dwarf milo.*

Dimensions.	Maximum.	Minimum.	Average.
	Millimeters.	*Millimeters.*	*Millimeters.*
Thickness	3.12	2.31	2.88
Width	5.05	2.69	4.47
Length	5.13	2.81	4.42

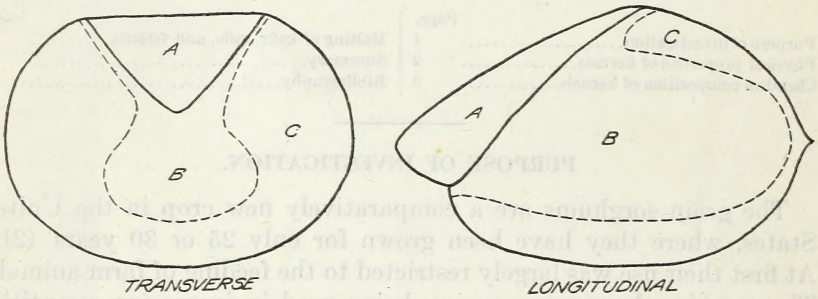

FIG. 1.—Sections of kafir kernels showing (*A*) germ, (*B*) starchy endosperm, (*C*) horny endosperm.

One thousand kernels of milo weighed 33.9 grams. Therefore, one kernel weighs on an average 0.0339 gram. Calculated from the measurements recorded in Table 1, the average volume of these kernels is 29.8 cubic millimeters and the surface of such a kernel is 48.3 square millimeters.

TABLE 2.—*Measurements of 50 kernels of dwarf feterita.*

Dimensions.	Maximum.	Minimum.	Average.
	Millimeters.	*Millimeters.*	*Millimeters.*
Thickness	3.12	2.28	2.76
Width	4.82	3.83	4.18
Length	4.85	3.76	4.39

One thousand kernels of feterita weighed 32.7 grams. Therefore, one kernel weighs on an average 0.0327 gram. Calculated from the measurements recorded in Table 2, the average volume of these

[2] The feterita and milo used in this work were obtained from the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, and were identified under the following numbers: Dwarf Milo C. I. 332 and Feterita C. I. 182.

kernels is 25.5 cubic millimeters and the surface of such a kernel is 44.9 square millimeters.

Table 3 gives the proportions of the component parts of the kernel.

TABLE 3.—*Proportion of component parts of kernels.*

Kernels.	Bran.		Germ.		Endosperm.	
	Proportion of kernel separated.	Average volume in kernel (calculated).	Proportion of kernel separated.	Average volume in kernel (calculated).	Proportion of kernel separated.	Average volume in kernel (calculated.)
	Per cent.	*Cubic millimeters.*	*Per cent.*	*Cubic millimeters.*	*Per cent.*	*Cubic millimeters.*
Corn	7.4	.....	11.5	.....	81.1	.....
Kafir	6.1	1.02	10.0	1.68	83.9	14.10
Milo	5.5	1.63	11.1	3.30	83.4	24.80
Feterita	6.6	1.68	7.3	1.86	86.1	21.93

The calculations in Table 3 are based on the assumption that the different parts of the kernel have the same specific gravity. On this assumption the thickness of the milo bran would average 0.033 millimeter, while that of the feterita bran would be 0.037 millimeter. It is realized that there are differences in the specific gravity of these tissues, but they are too small to affect the conclusions here drawn.

CHEMICAL COMPOSITION OF KERNELS.

Table 4 gives a comparison of the composition of the whole kernels of the kafir, milo, and feterita, on a water-free basis.

TABLE 4.—*Comparison of composition of kafir, milo, and feterita kernels on a water-free basis.*

Kernels.	Proportion of kernel.	Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen-free extract.	Starch.	Pentosans.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Kafir	100	1.80	4.10	12.70	1.80	79.60	61.90	3.30
Milo	100	1.89	3.47	13.99	1.93	78.72	68.52	3.95
Feterita	100	1.79	3.06	16.69	2.22	76.24	64.16	3.38

In these comparisons the greatest differences are observed in the protein and starch content. The other results show little variation.

In Tables 5, 6, 7, and 8 comparisons are made between the parts of the corn and kafir kernel and the corresponding parts of the milo and feterita kernel.

TABLE 5.—*Comparison of corn hulls and kafir bran with milo and feterita brans.*

Material.	Proportion of kernel.	Ash.	Ether extract.	Protein.	Crude fiber.	Carbohydrates.	Starch.	Pentosans.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corn hulls	7.4	0.79	0.89	3.96	.....	94.38	.....	.....
Kafir bran	6.1	2.00	6.80	4.80	16.20	70.20	.....	18.40
Milo bran	5.5	3.07	4.33	7.08	15.36	70.16	1.60	21.35
Feterita bran	6.6	2.95	5.74	6.85	13.56	70.90	3.89	15.79

In studying these results it will be noted that the amount of ash and ether extract in the corn hulls is decidedly lower than that in the bran of kafir, milo, or feterita. These determinations in the kafir, milo, and feterita appear to resemble one another fairly closely.

TABLE 6.—*Comparison of corn and kafir horny endosperm with milo and feterita horny endosperm.*

Horny endosperm.	Proportion of kernel.	Ash.	Ether extract.	Protein.	Crude fiber.	Carbohydrates.	Starch.	Pentosans.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corn	55.6	0.44	1.15	11.85	.....	86.56	.....	.....
Kafir	48.9	.30	.70	14.50	0.70	83.80	68.80	0.70
Milo	54.7	.56	.15	15.11	.69	83.49	72.24	.69
Feterita	61.1	.71	.33	19.75	2.12	77.09	60.36	2.12

The most noticeable differences among these results are in the comparatively high fat content of the corn and the comparatively high protein content of feterita.

TABLE 7.—*Comparison of corn and kafir starchy endosperm with milo and feterita starchy endosperm.*

Starchy endosperm.	Proportion of kernel.	Ash.	Ether extract.	Protein.	Crude fiber.	Carbohydrates.	Starch.	Pentosans.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corn	25.5	0.26	0.24	7.84	.....	91.66	.....	.....
Kafir	35.0	.30	.80	11.66	0.80	86.44	70.40	1.90
Milo	28.7	.71	.28	8.91	.81	89.29	82.50	4.35
Feterita	25.1	.96	.64	10.61	2.38	85.41	75.84	4.66

These results show a marked similarity, the protein content being slightly higher in the kafir than in the other grains.

TABLE 8.—*Comparison of the corn and kafir germ with the milo and feterita germ.*

Germ.	Proportion of kernel.	Ash.	Ether extract.	Protein.	Crude fiber.	Carbohydrates.	Starch.	Pentosans.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corn	11.5	9.90	34.84	19.80	.....	35.46	.....	.....
Kafir	10.0	13.20	31.50	19.30	3.80	32.20	.....	6.10
Milo	11.1	9.46	19.92	20.84	9.11	40.67	1.53	8.57
Feterita	7.3	11.35	25.45	21.70	8.54	32.96	2.16	6.95

In Table 8 notice is immediately taken of the low ether extract of the milo germ. The other results show a great similarity.

A general consideration of all the tables shows that the protein content of the feterita is higher than that of the other grains. The horny endosperm in each case has more protein than the starchy endosperm. The germs of these sorghums are very similar in composition.

MALTING OF KAFIR, MILO, AND FETERITA.

While the work just reported was in progress the question of the diastatic power of malts made from these sorghums arose. For some time little attention has been paid to grains other than barley for malting purposes, as this grain has served the brewing industry satisfactorily. However, it was thought that a comparison of the diastatic power of barley with that of the sorghums, kafir, milo, and feterita might be of value.

MALTING PROCESS (5).

The grain was washed free from chaff, weed seeds, and other foreign material, covered with clean, fresh water, and allowed to stand for 12 hours, the water being replaced once or twice during this period. The water was then removed and the grain was allowed to stand for an additional 12 hours. This entire operation was repeated for such a time as was required to bring about complete steeping. The grain was considered thoroughly steeped when it could be crushed between the thumb and fingers and the inside was not hard or glassy, but soft and chalklike.

SPROUTING.

After the water had been removed the steeped grain was allowed to germinate at a temperature of 15.5° C. In about six days the sprouts which had been developing inside the seed coat forced their way out at the end of the grain opposite the rootlet. The germination was continued for from 8 to 14 days, or until the sprouts were about three or four times the length of the grain.

DRYING.

All moisture possible was expelled, at first at room temperature and finally at 40° C. It was found especially advantageous to observe the following precautions (4). To prevent molding as much as possible, the grain after being washed and soaked for one hour in water was allowed to stand for one-half hour in 0.24 per cent solution of formaldehyde, after which the steeping in water already described was continued. The grain was germinated between approximately sterile damp towels to prevent molding and drying, the towels being replaced every other day.

COMPARISON OF TEMPERATURE, TIME OF STEEPING, AND TIME OF GERMINATION OF GRAIN SORGHUMS.

A comparison of the temperature, time of steeping, and time of germination of the grain sorghums investigated is shown in Table 9.

TABLE 9.—*Comparison of temperature, time of steeping, and time of germination of grain sorghums.*

Malt.	Time of steeping.	Time of germination.	Average daily temperature during germination.
	Hours.	*Days.*	*° C.*
Kafir	30	14	17
Milo	30	8	20
Feterita	22	10	20

The difference in the time of steeping shown in Table 9 is due to the capacity of the various grains to absorb water, this capacity being governed principally by the hardness and compactness of the grain. The interior starchy portion of the kafir and milo kernels is harder and more glassy than that of the feterita, and consequently requires a longer time for the complete absorption of water. The time of germination varies in each case, but is governed to a large extent by the temperature. The grain required a shorter time for germination in cases where the temperature was higher.

DIASTATIC POWER OF MALTED GRAIN SORGHUMS.

After the malting was completed the finished malt was analyzed by the following methods:

Preparation of sample.—After the malt had been thoroughly mixed and a uniform sample taken, it was ground to pass a 20-mesh sieve.

Moisture.—Two grams of the ground malt was accurately weighed in a covered weighing dish and dried at 60° C. in a vacuum to constant weight.

Diastatic power (3).—Twenty-five grams of ground malt was extracted with 500 cubic centimeters of distilled water (free from ammonia, nitrates, etc.) for 3 hours at 21° C. and filtered. The first 100 cubic centimeters of the filtrate was rejected. Then 100 cubic centimeters of a 2 per cent starch solution (soluble starch prepared according to Lintner) was treated with 1 cubic centimeter of the malt extract of diastase solution for 1 hour at 21° C., 50 cubic centimeters of Fehling solution was added, and the whole was heated rapidly to 98° C. It was next placed in a boiling water bath for seven minutes, and, without being diluted, the cuprous oxid was filtered immediately, dried, and weighed. The weight of cuprous oxid was calculated to copper by the following factor: $\frac{Cu_2}{Cu_2O}=0.8882$. The weight of copper found minus the weight of copper reduced by 100 cubic centimeters of the 2 per cent starch solution (determined by a blank on this amount carried through the regular procedure) was divided by 0.441 (gram of copper in 50 cubic centimeters of Fehling solution), and this result, multiplied by 100, gave the Lintner value.

Acidity.—Fifty grams of ground malt was digested with 300 cubic centimeters of distilled water at 15.5° C. for three hours. The acidity of the filtered extract was measured by titrating against N/20 sodium hydroxid and calculated to percentage of lactic acid.

A comparison of the diastatic power of some of the malted grain sorghums with that of a barley is shown in Table 10.

TABLE 10.—*Comparison of the diastatic powers of barley, kafir, feterita, and milo malts.*

Malt.	Moisture.	Diastatic power.		Acidity as lactic acid.	
		Moisture basis.	Dry basis.	Moisture basis.	Dry basis.
	Per cent.	*Degrees.*	*Degrees.*	*Per cent.*	*Per cent.*
Barley	6.73	162.4	174.1	0.176	0.189
Kafir	6.88	9.5	10.2	.221	.227
Feterita	5.22	35.0	36.9	.....	.....
Milo	5.97	35.3	37.5	.....	.....

The sample of barley malt shown in Table 10 is of exceptionally high diastatic power, being much higher in diastase than the ordinary dried brewing malts, which range between 20° and 40° Lintner, and therefore can not be taken as an average representative of that type. From the standpoint of the brewer, the color, flavor, and percentage of soluble material play a very important part, and the diastatic power is sacrificed to some extent to bring about these factors through the action of heat during drying. The grain sorghums shown in Table 10 were malted under conditions that would give the highest possible diastatic power, the other requirements of a good brewing malt being sacrificed to obtain this property.

The acidity of the kafir malt was determined as a check on the malting process for the purpose of showing that the acidity was not high enough to have any effect upon the diastatic power.

The results obtained show conclusively that the sorghums investigated do not meet the requirements of a green malt. The diastatic power of these sorghums, with the exception of kafir, is comparable with that of dried malts, when malted under conditions that would give the highest possible diastatic power. When subjected to temperatures that would give the color and flavor required in a dried malt, however, this diastatic power would be too low for all practical brewing purposes.

SUMMARY.

On the whole, the kafir, corn, milo, and feterita resemble one another in composition and appearance. The proximate constituents of the kernels of these four sorghums indicate their value as food for man and domestic animals, and show the possibility of their being used as raw products in certain important commercial operations having for their purpose the manufacture of starch, sirup, alcohol,

and oil, when proper machinery and processes have been devised. It has been found, however, that it would probably be impracticable to use them commercially for malting purposes.

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